

Position Paper

Advantages of using nitrogen as a pest treatment of cultural heritage items

Museums in member states of the European Union are currently unable to use in-situ generated nitrogen to treat pest insect infestations of cultural heritage items. This is a significant setback for the cultural heritage conservation community, restricting the choice of treatments, which must be addressed urgently. ICOM UK considers that the European Commission, in conjunction with the Competent Authorities of EU member states, should pave the way for re-establishing the ability of cultural heritage organisations to use nitrogen anoxia as a routine pest insect treatment methodology.

Introduction

The ICOM UK national committee supports the serious concerns of British museums over the unavailability of the technology of a controlled nitrogen atmosphere (in situ generated nitrogen used in a sealed chamber) to protect cultural heritage from pest insect infestation by in situ generation of nitrogen.

Unlike other sustainable insect disinfection methods, the displacement of atmospheric oxygen can be used on almost any cultural heritage material. The procedure has been used increasingly by museums and other heritage institutions since the 1980s to generate an anoxic environment with the aim of killing insect pests attacking historic and art objects (Berzolla et al. 2011) and is included in the European Standard EN16790:2016 „Conservation of cultural heritage – Integrated pest management (IPM) for protection of cultural heritage“.

Conventional fumigants can have adverse effects on various materials (Linnie 1994), and some fumigants or their reaction products are retained in artefacts for long periods (Florian 1987). Additionally, many fumigants are harmful to human health. Methyl bromide has been used as an effective control measure to disinfest artefacts, but it is being banned worldwide due being an ozone-depleting substance (Phillips et al. 2011).

No pest insect treatment method is likely to be safer or more protective of the integrity of objects than the use of a controlled atmosphere with low or no oxygen. For the operation of in situ treatment facilities, nitrogen is separated from ambient air directly at the place of use and stored in a container. During treatment the nitrogen content of the atmosphere in a treatment chamber is increased to >99% and oxygen is almost completely displaced. At the same time,

relative humidity and temperature in the treatment chamber are controlled. The duration of an object treatment may be up to several weeks. Under these conditions, harmful insects cannot survive.

Nitrogen treatment has many advantages, including:

- It can be used for the treatment of almost all cultural objects.
- It can be applied to objects made from materials that cannot be committed to other types of pest insect treatments, such as freezing or heat treatments - typically objects made of organic materials or a combination of materials.
- It is effective against all life stages of harmful insects.
- It is cost effective, quick and easy to undertake and independent from private suppliers at those museums which have a nitrogen generator and treatment chamber.
- The European Standard EN16790:2016 „Conservation of cultural heritage – Integrated pest management (IPM) for protection of cultural heritage“ includes the method in Annex E.4. as „Anoxia or modified/controlled atmospheres“ with the goal of killing insects.
- Nitrogen is listed in Annex I of the Biocidal Products Regulations and hence classified as substance with a favourable environmental and health profile.

Since the mandatory registration of the use of nitrogen for insect pest disinfestation purposed by the Biocidal Products Regulation EU 528/2012 in September 2017 (BPR), only one method of nitrogen use (along with several other restrictions) has been acknowledged and included: nitrogen in cannisters. The use of in situ generated nitrogen in anoxia chambers has not been included in the new regulation and because of this legislative flaw, existing anoxia facilities in Europe can no longer be used.

In the UK, there is presently only one authorisation for a biocidal product with the active substance nitrogen in cannisters under the product name „Rentokil N2 Controlled Atmosphere“. The existence of a single licence cannot ensure a constant product availability required for frequent applications. Rentokil does not appear to have the resources to undertake this treatment, resulting in the continued use of chemical fumigations, such as phosphine, in the UK. Phosphine can cause corrosion of various metals including gold (Dawson & Strang 2000). Similarly, two museums in Austria asked Rentokil for a nitrogen treatment in 2018, but the service could not be provided by the company. Furthermore, treatment with nitrogen from read-to-use canisters in ‘tents’ that can be humidity controlled but do not leak is technically difficult to achieve, whereas both these issues are less of a problem in nitrogen chambers.

An alternative to fumigating artefacts or anoxic treatment is to expose them to very low or high temperatures. However, research on the effects of exposure to extreme temperatures has not dispelled concerns regarding the safety of all types of objects under such conditions. Thus, temperature-controlled treatments are

limited to cultural heritage objects comprising of thermally robust materials (Makaewa 2003).

In July 2019, the commercial supplier Thermo Lignum International GmbH contributed to this discussion by submitting a letter to the European Commission which ICOM UK feels is motivated by commercial interests. In this letter, Thermo Lignum International GmbH argues that derogation should be limited to non-commercial applications by cultural or governmental institutions and that the user categories for the biocidal products authorised under a derogation should be limited to trained staff members of cultural and governmental institutions.

As Museums do not operate nitrogen-generating facilities for financial profit they do not have any commercial interests. The purpose of museums, many of which are in public ownership, is to ensure the long-term preservation of cultural heritage objects.

Evidence: Nitrogen is safer than other methods

Any treatment applied to cultural heritage items should not alter the visual, structural or scientific integrity of an object. These requirements restrict the use of alternative treatment procedures, such as biocides, high and low temperatures, and radiation, for certain types of objects.

Many heritage items comprised of organic materials which are potentially subject to pest insect attack are made from a composition of different materials. The decision which method to apply in case of an insect infestation is largely affected by the physical and chemical properties of the materials comprising the object. Any potentially irreversible changes (damage) to the object are not acceptable.

1. Treatment of cultural heritage objects in a controlled atmosphere provides a stable environment where physical and chemical deterioration is less likely (Selwitz & Maekawa 1998). Controlled atmospheres were developed to control insect pests in stored grains (Carpenter & Potter 1994, Banks & Annis 1990). A controlled atmosphere may comprise inert gases (helium, nitrogen), low oxygen levels (<2%), high CO₂ (5-60%), or combinations of the above (Bailey 1957, [Tunc 1983](#), [Tunc & Navarro 1983](#)). Controlled atmospheres using nitrogen represent a safe, effective and environmentally friendly method for both objects and human health.

2. Improved protection for light-sensitive dyes and pigments can be attained by replacing air with nitrogen (Kuhn 1968). Kuhn (1968) suggested a design for a museum case in which the concentration of oxygen is kept very low by maintaining a flow of nitrogen into it, thus creating a positive pressure and allowing humidification of the nitrogen, which is usually essential for organic materials. Whilst rates of fading are decreased at lower levels of relative humidity and temperature, the exclusion of oxygen has an even greater effect on decreasing fading rates.

3. Studies by Burke (1992) and Arney et al. (1979) showed that the longevity of most organic colours is increased significantly in a nitrogen atmosphere with less than 1000 ppm oxygen. A small number of dyes exhibit greater amounts of fading and colour change in the presence of a reduced-oxygen atmosphere (Buss & Crews 2000), but Buss and Crews (2000) determined that for those dyes exhibiting a colour change under a low-oxygen atmosphere, the reaction was photochemical in nature. Hence, the unwanted colour change may be avoided during anoxic treatments by conducting anoxic pest control treatments in the dark.

One exception appears to be Prussian blue; anoxic treatment of textiles dyed with Prussian blue caused fading and chemical change in the pigment, although following re-exposure to air the colour may recover fully (Rowe 2004). The fading is due to the reduction of Fe³⁺ to Fe²⁺, a process which is commonly associated with contact with the substrate (Gervais et al. 2013) or light exposure (Gervais et al. 2014). Rowe (2004) recommends caution when treating historic textiles dyed with Prussian blue, since deteriorated dye may not recover from fading as well as the modern samples tested at the same time.

4. Koestler et al. (1993) assessed the impact of the two gases on thirty combinations of linen, rabbit-skin-glue, lead-white oil ground, and oil-based paints employing eleven different inorganic pigments. One set of samples were treated with sulfuryl fluoride by a commercial exterminator; a second set of samples were kept under nitrogen for five months. Following the treatments, impurities in the sulfuryl fluoride (hydrogen chloride and sulfur dioxide) were found to have adversely affected ten of the eleven pigment samples, while nitrogen had no observable negative effect on any sample.

5. In addition to the benefits of an anoxic environment for retarding the fading of colourants, there have been applications for parchment (collagen; 1951 report of the National Bureau of Standards (NBS); Kanagy 1940); paper (cellulose; Preservation Capsule 1968; Passaglia, Brown, and Dickens 1980; Weaver 1980) and, to a much lesser extent, metals (Salins and France-Lanord 1943:26; France-Lanord 1949; Bulst 1986; cf. also Maekawa 1998). An inert-gas atmosphere has also been suggested, and implemented, for the storage of mummified remains of humans and animals (David 1986).

Table 1: Materials for which anoxic or low oxygen treatment is safer than freezing or heating.

Material	Risks during freezing/heating	Reference
Vegetable-tanned leather	Leather-bound historic books can sustain irreversible shrinkage.	Beiner & Ogilvie 2005
Papyrus	Irreversible material changes.	Beiner & Ogilvie 2005

Adhesives, resins	Dimensional changes, discolouration, crazing, embrittlement, weight loss.	Ball et al. 2011, Tscherne 2009, Tscherne et al. 2016
Animal products	Phase changes in proteinaceous materials.	Beiner & Ogilvie 2005
Biological material potentially used for DNA studies	Denaturing of DNA.	Ackery et al. 2004

More research on potentially negative effects of heat treatment is still required for many materials, such as ivory, plastics, mother-of-pearl, photographs, and any objects containing wax as a component.

There are currently twelve Thermo Lignum chambers built in Europe, contrasting with almost 40 nitrogen chambers in Germany and Austria alone. This is testament to the versatility of nitrogen anoxia over other pest treatment options in the cultural heritage sector.

Situation in the UK

Whilst not as commonplace as in, for example, Germany and Austria, at least one museum in the UK has an in-situ nitrogen generator and treatment chamber which were in use until the BPR came into force. Nitrogen treatment was cheap and effective, and independent from commercial suppliers.

Presently, the only possibility of undertaking anoxic treatment using a nitrogen atmosphere is through a single commercial contractor who does not have the required equipment nor expertise to offer this service across the sector. The change to the law has created a de facto monopoly making it impossible for museums to compare the costs of different suppliers and creating a dependency on the sole supplier. The supplier’s licence expires in 2021 which creates additional uncertainty. The only feasible alternative to the use of nitrogen is a carbon dioxide bubble, which is less cost-effective and less environment friendly.

A way forward

The current situation is a significant setback for the cultural heritage conservation community, restricting the choice of treatments which must be urgently addressed. ICOM UK acknowledges it would be difficult to re-classify nitrogen and remove its current status as a biocide even though there is evidence that nitrogen does not illicit a toxic response and, hence, there are grounds for not considering it a biocide. The nitrogen ban can only be justified on the grounds of legislative and procedural reasons.

In principle, nitrogen can be approved for use under the BPR on the basis that it does not meet any of the criteria that would exclude approval. Exclusion criteria include:

- carcinogens, mutagens and reprotoxic substances categories 1A or 1B according to the CLP Regulation;
- endocrine disruptors;
- persistent, bioaccumulative and toxic (PBT) substances;
- very persistent and very bioaccumulative (vPvB) substances.

Product registrations through the European Chemicals Agency and derogations through national governments are both foreseen by the BPR, in particular when the active substance may be needed on the grounds of public health or of public interest when no alternatives are available. Derogations according to Art. 55 (3) BPR are special exceptions from the BPR's fundamental principal of Art. 19 (1) (a) BPR, which stipulates that biocidal products other than those eligible for the simplified authorisation procedure in accordance with Article 25 BPR shall be authorised if the active substances are included in Annex I or approved for the relevant product type and any conditions specified for those active substances are met. A derogation according to Art. 55 (3) BPR requires that the active substance is essential for the protection of cultural heritage and that no appropriate alternatives are available.

This position paper demonstrates that there are many applications in which in-situ generated nitrogen cannot be substituted by appropriate existing alternatives. Indeed, for many types of cultural heritage objects no appropriate alternative to nitrogen treatment exists.

ICOM UK considers that re-establishing the ability of cultural heritage organisations to use nitrogen anoxia as a routine pest insect treatment methodology is important and necessary.

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